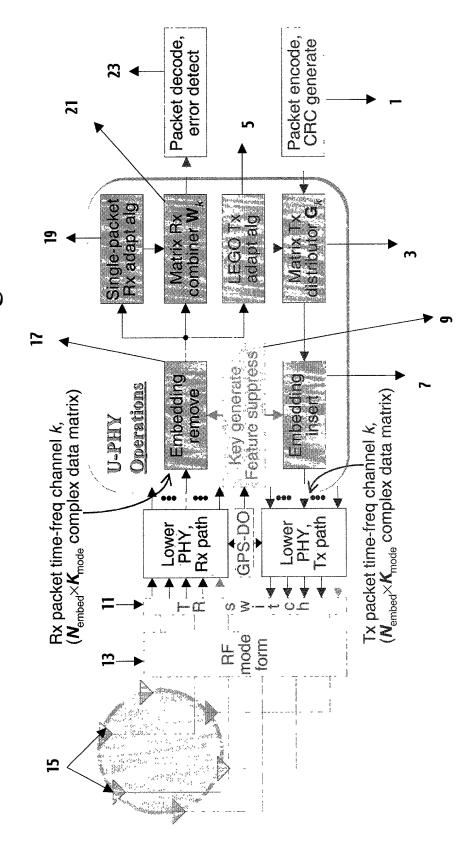
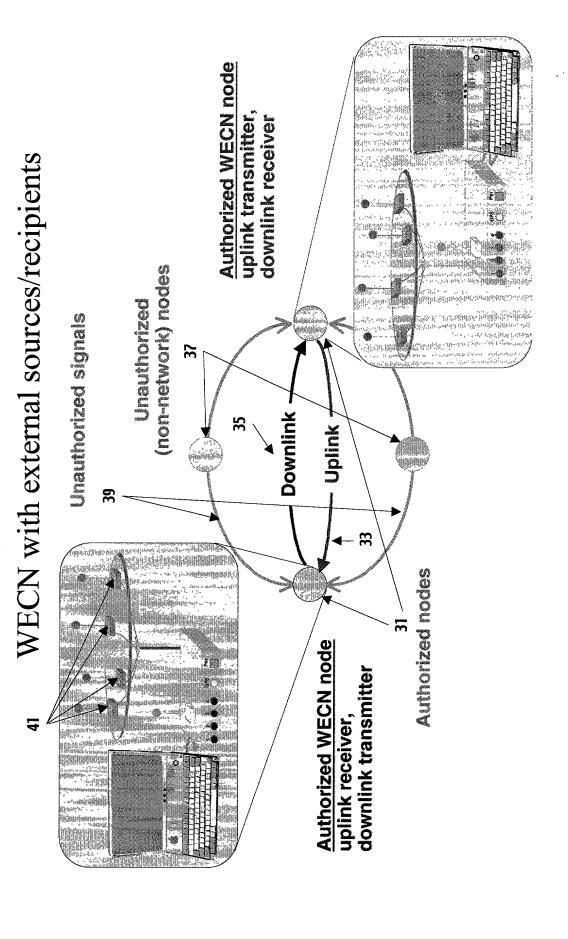
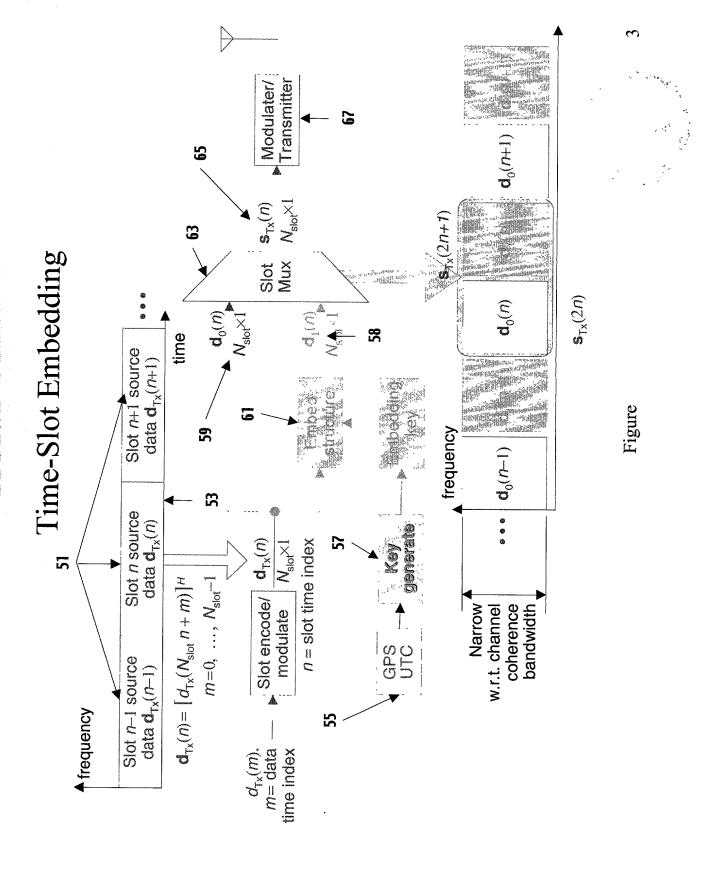
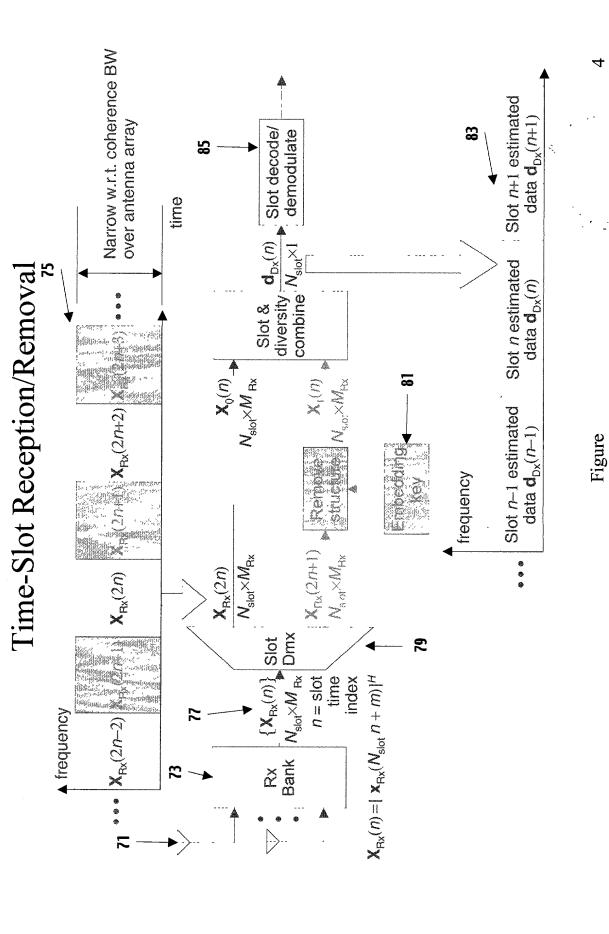
### WECN Structural Embedding/Removal



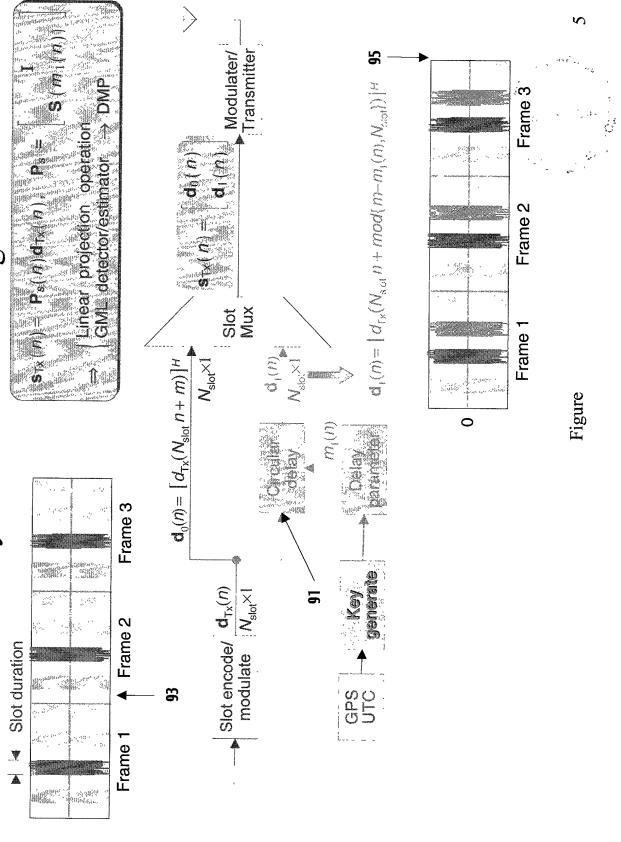
Figure

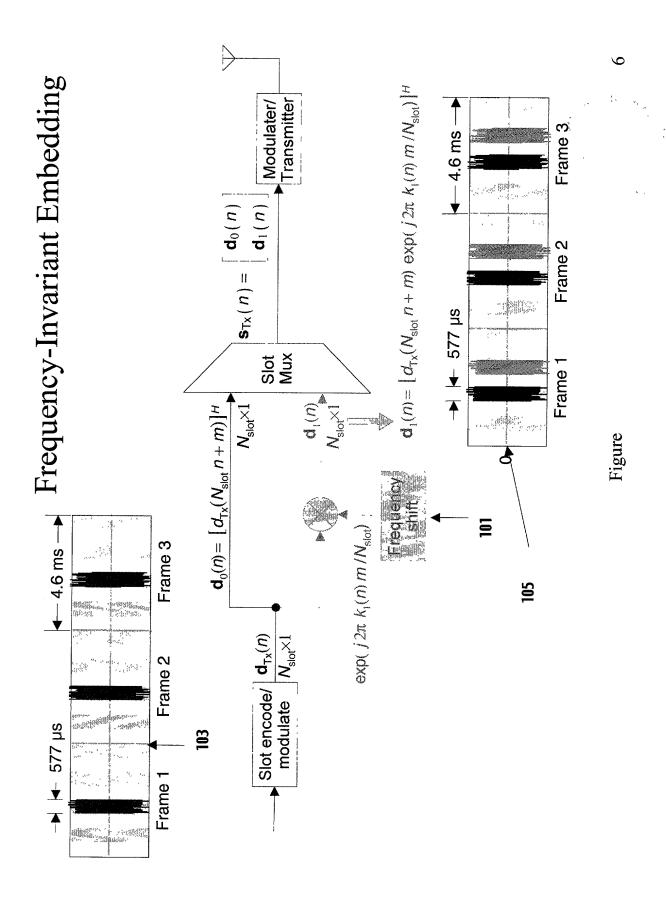


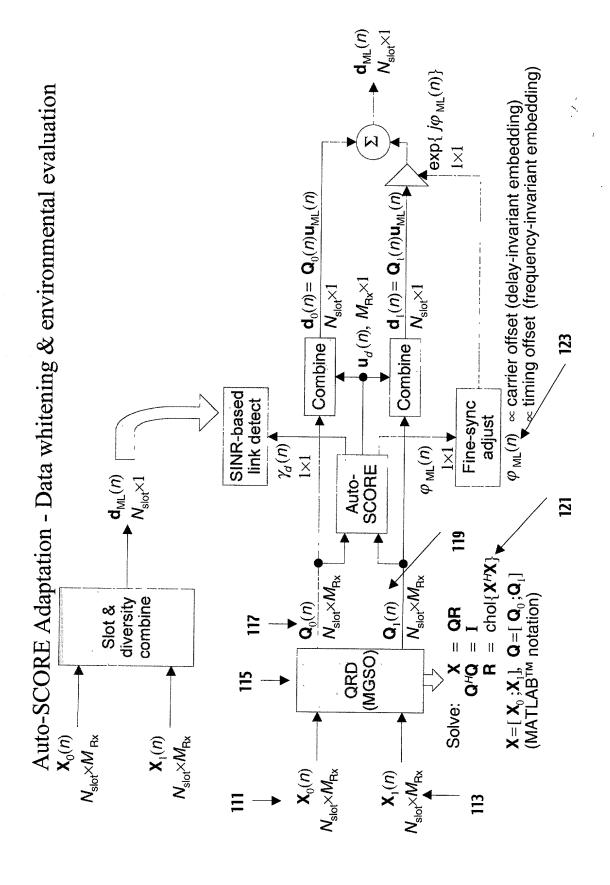




### Delay-Invariant Embedding







## Single-Link Auto-SCORE Algorithm - Software

Combine  $N_t \times M$  matrices  $X_0$  and  $X_1$  into single  $2N \times M$  matrix X,

Iteratively update combiner weights (preset iterations, or until stopping criterion met)

 $v = \mathbf{Su}$   $\rho = 1/2 \operatorname{sign} \{\mathbf{v}^{H}\mathbf{u}\}$   $\mathbf{u} \leftarrow \rho \mathbf{v} + \rho^{*}\mathbf{S}^{H}\mathbf{u}$   $\mathbf{v} = ||\mathbf{u}|| (\mathbf{L}_{2} \operatorname{norm})$ 

 $\Lambda/n \rightarrow n$ 

$$\mathbf{X} = [\mathbf{X}_0{}^H \, \mathbf{X}_1{}^H]^H$$

where  $N = N_{\text{slot}}$ ,  $M = M_{\text{Rx}}$  if time-slot embedding is employed at the transmitter. Compute **QR** decomposition of X,

$$X = QR$$

$$\mathbf{A} = \mathbf{A}\mathbf{K}$$

 $\mathbf{Q}^H \mathbf{Q} = \mathbf{I}$  $\mathbf{R} = \operatorname{chol}\{\mathbf{X}^H \mathbf{X}\},\$ 

Compute output SINR measurement  $\gamma$ 

 $\gamma = \nu/(1-\nu)$ 

where Q is defined by

$$\mathbf{Q} = [\mathbf{q}_1 \dots \mathbf{q}_M]$$
  
=  $[\mathbf{q}(1) \dots \mathbf{q}(N)]^H$ 

Separate Q into  $N \times M$  submatrices  $Q_0$  and  $Q_1$ , such that

Exit

 $\gamma \geq \gamma_{\text{detect}}$ ?

$$O_n = X_nC$$

$$\mathbf{Q}_0 = \mathbf{X}_0 \mathbf{C}$$
$$\mathbf{Q}_1 = \mathbf{X}_1 \mathbf{C},$$

where  $C = \mathbb{R}^{-1}$ . Form  $M \times M$  cross-correlation matrix S,

Compute slot/diversity combined output data

 $\mathbf{d} = \mathbf{Q}_0 \mathbf{u} + (\mathbf{Q}_1 \mathbf{u}) e^{-j\varphi}$ 

Compute phase-shift estimate  $\phi$ ,

yes

$$\mathbf{S} = (1/N) \mathbf{Q}_0^H \mathbf{Q}_1$$

$$= [s(m,M)]$$
  
=  $||\mathbf{u}|| (I, norm)$ 

$$\mathbf{u} = [s (m, M)]$$

$$\mathbf{v} = ||\mathbf{u}|| (L_2 \text{ norm})$$

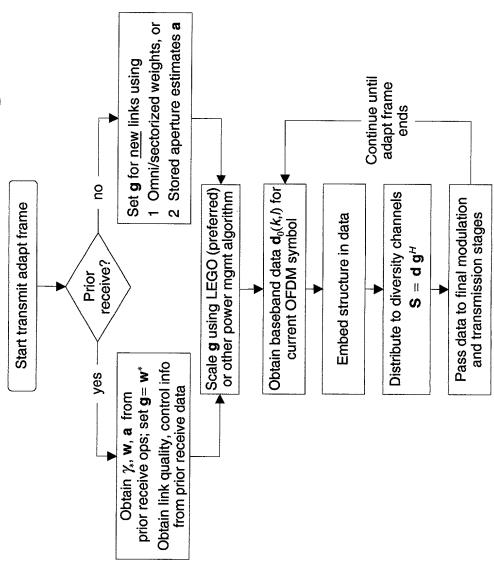
$$\mathbf{u} \leftarrow \mathbf{u}/v$$

Compute unwhitened combiner weights w, aperture vector a, Initialize whitened linear combiner weights

$$\mathbf{w} = \mathbf{C}\mathbf{u}$$

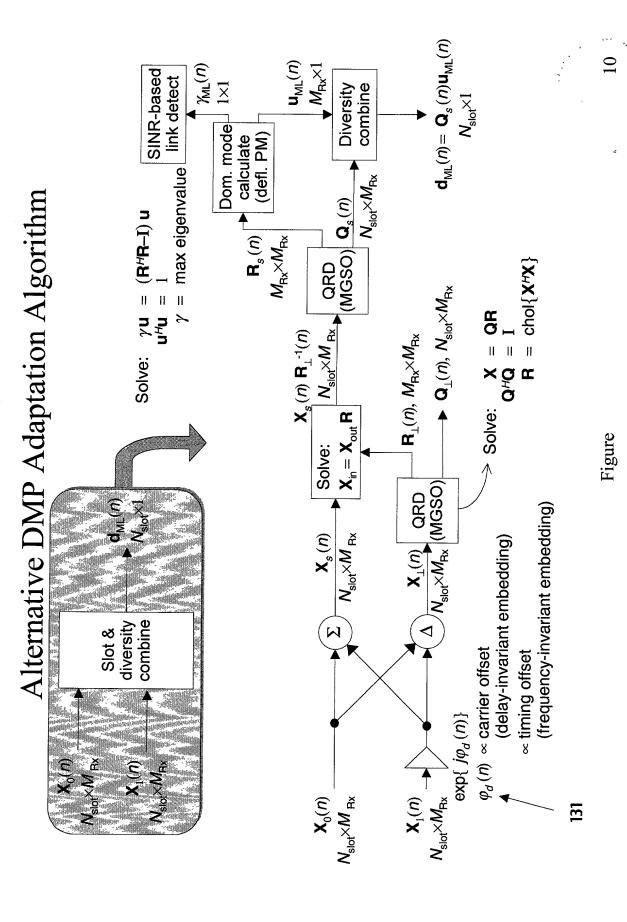
$$\mathbf{a} = \mathbf{R}^H \mathbf{n}$$





Figure

6



# alternative converging embedded-signal-differentiation

#### algorithms

### **Dominant-Mode Prediction**

Solve:  $\gamma \mathbf{u} = (\mathbf{R}^H \mathbf{R} - \mathbf{I}) \mathbf{u}$   $||\mathbf{u}|| = 1 (\mathbf{L}_2 \text{ norm})$   $\gamma = \text{max eigenvalue}$ 

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Solve:

 $V(\varphi) \mathbf{u} = \mathbf{S}(\varphi) \mathbf{u}$   $\mathbf{S}(\varphi) = 1/2(\mathbf{S}e^{j\varphi} + \mathbf{S}^He^{-j\varphi})$   $||\mathbf{u}|| = 1 \ (L_2 \text{ norm})$ 

 $v(\varphi) = \max \text{ eigenvalue}$  $\varphi = \arg \max_{\varphi} v(\varphi)$ 

#### **Optimization Algorithm**

Initialize:  $\mathbf{u} = r(M, M) [r^*(M, 1) - 1]$   $\gamma = ||\mathbf{u}|| (L_2 \text{ norm})$   $\mathbf{u} \leftarrow \mathbf{u}/\gamma$ 

Iterate:

 $\begin{array}{ll}
\mathbf{u} \leftarrow \mathbf{R}^H \mathbf{v} - \mathbf{u} \\
\gamma = \|\mathbf{u}\| \ (\mathbf{L}_2 \text{ norm}) \\
\mathbf{u} \leftarrow \mathbf{u}/\gamma
\end{array}$ 

#### **Optimization Algorithm**

Initialize:

 $\mathbf{u} = [s(m, M)]$   $v = ||\mathbf{u}|| (L_2 \text{ norm})$   $\mathbf{u} \leftarrow \mathbf{u}/v$ 

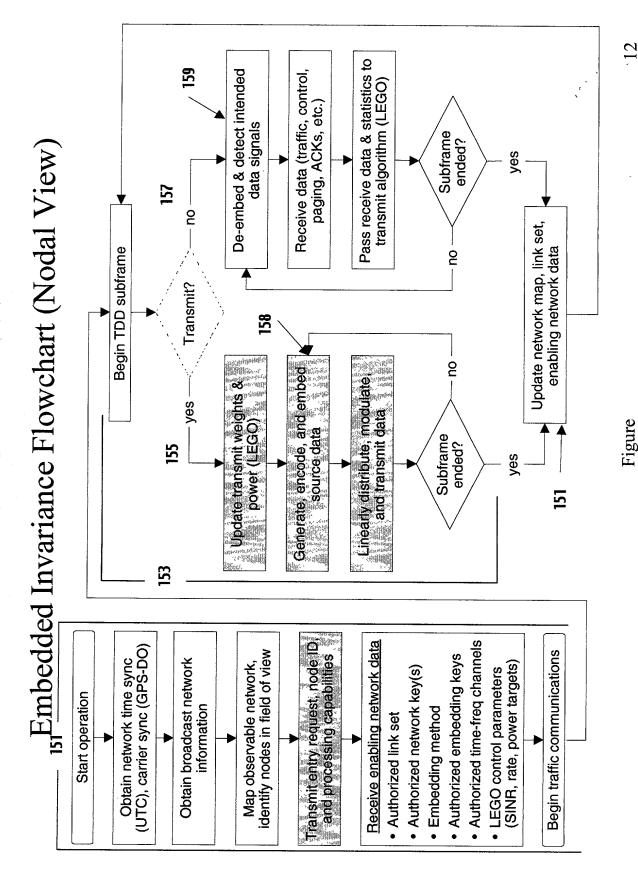
Iterate:

 $\rho = 1/2 \text{ sign}\{\mathbf{V}^H\mathbf{u}\}$ nysed ナスグシn

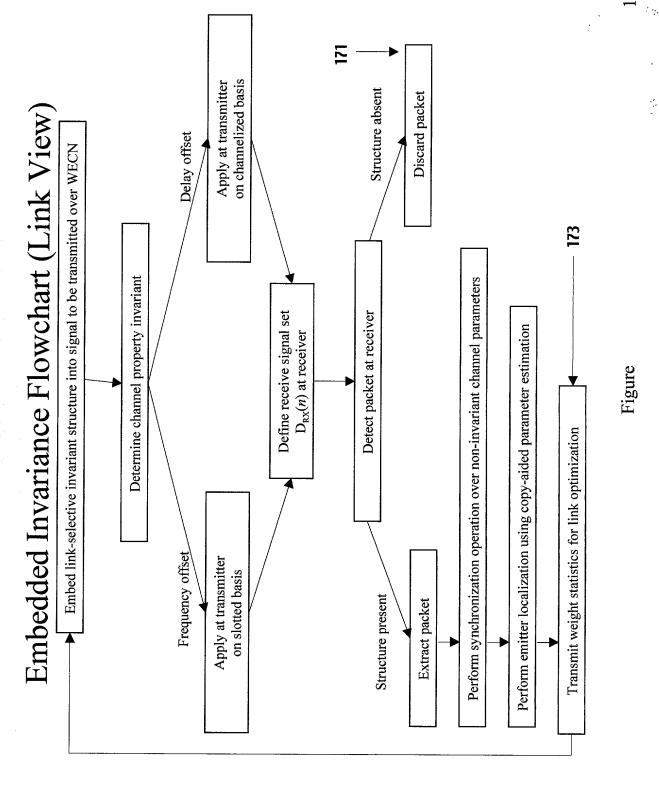
 $v = ||\mathbf{u}|| \quad (\hat{\mathbf{L}}_2 \text{ norm})$  $\mathbf{u} \leftarrow \mathbf{u}/v$ 

Finalize:

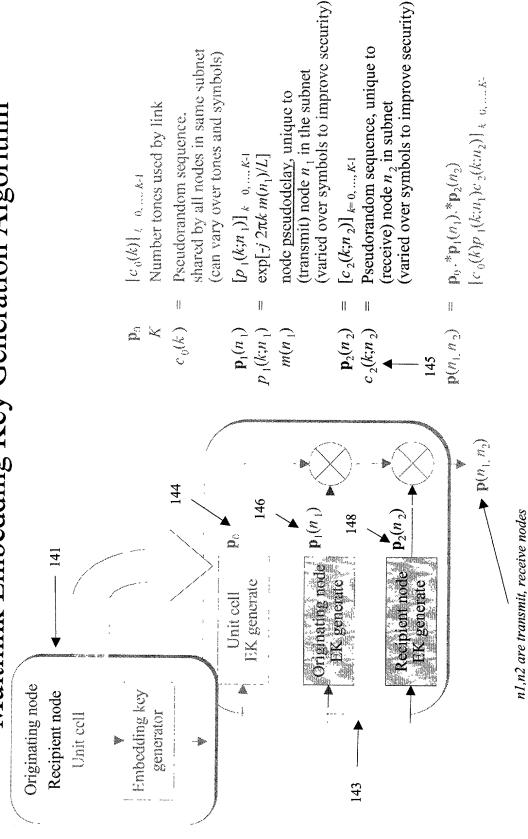
 $\varphi = \arg\{\rho\}$  $\gamma = \nu/(1-\nu)$ 



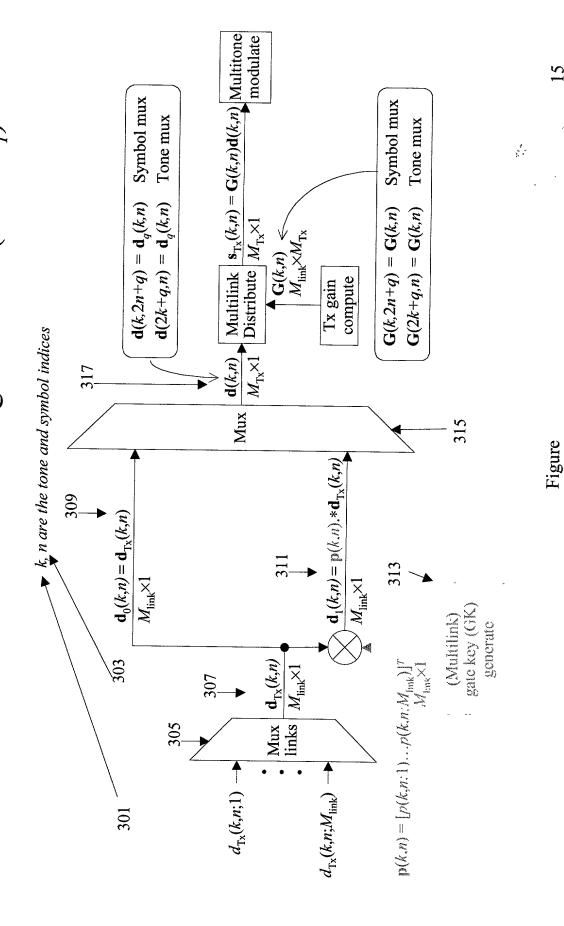
Figure

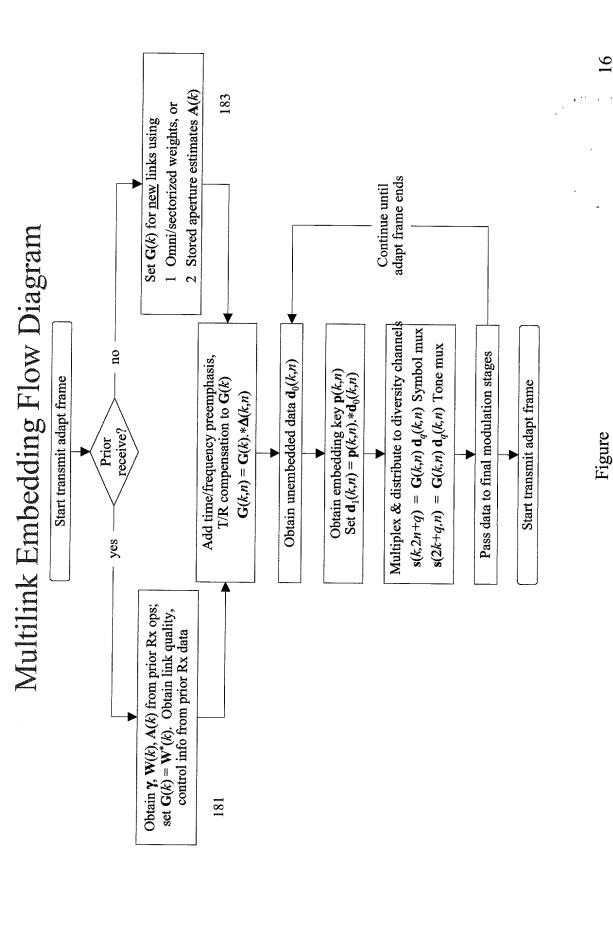


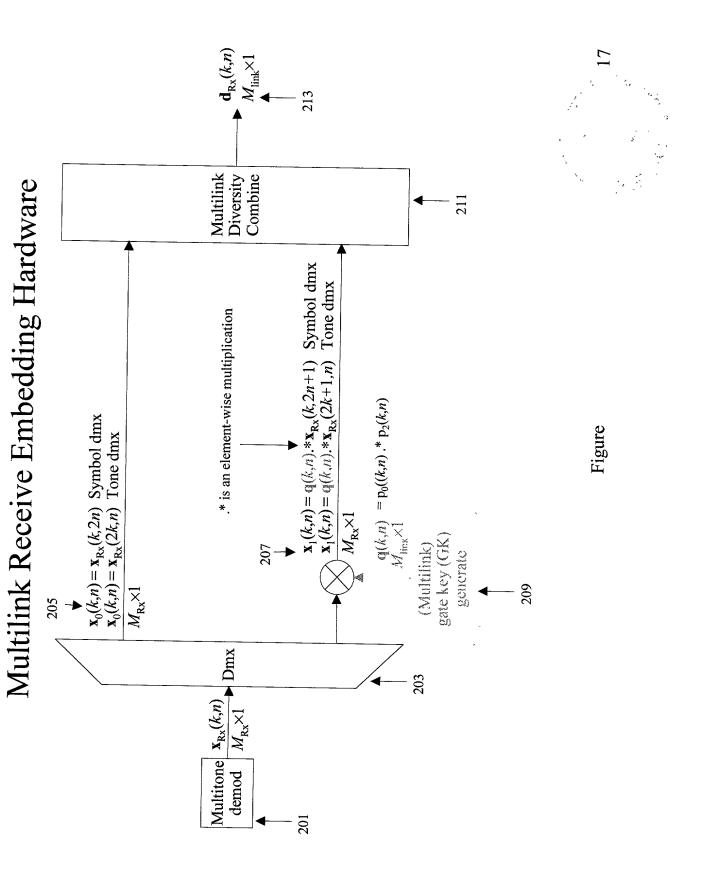
## Multilink Embedding Key Generation Algorithm

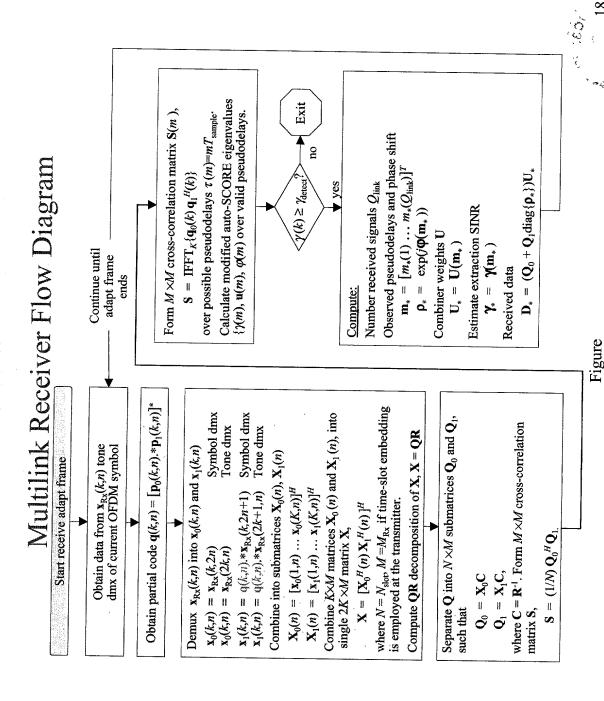


## Multilink Transmit Embedding Hardware (Node $n_1$ )

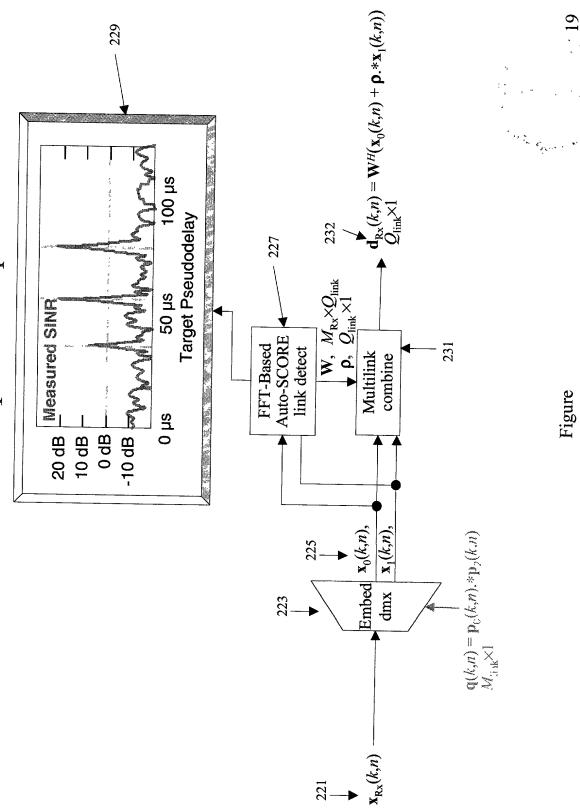








Link Detection, Separation Operation



Pseudodelay Plots and Antenna Patterns

